Heavy flavor in sPHENIX

Tony Frawley
Florida State University

sPHENIX Collaboration Meeting
Rutgers, December 9-12, 2015

Heavy flavor in sPHENIX - what might we do?

Closed heavy flavor
- Y to e^+e^-
- J/ψ to e^+e^- ?

Requires:
- Electron ID (hadron rejection)
- Precise tracking for momentum resolution

Open heavy flavor
- B-tagged jets
- Reconstructed D mesons
- B to J/ψ

Requires:
- Precise vertexing
- Good tracking resolution
- Low fake track rates

Heavy quarkonia

Heavy quarkonia become unbound at different temperatures, depending on their radius - so they are sensitive to physics at different length scales (e.g. color screening).

However the modification of heavy quarkonia yields in nuclear collisions is caused by an interplay of:

- Energy density
- Coalescence
- Cold nuclear matter effects

All of these are significant contributors, and to study the effects of color screening on quarkonia bound states we need to understand the role played by all three of these effects.
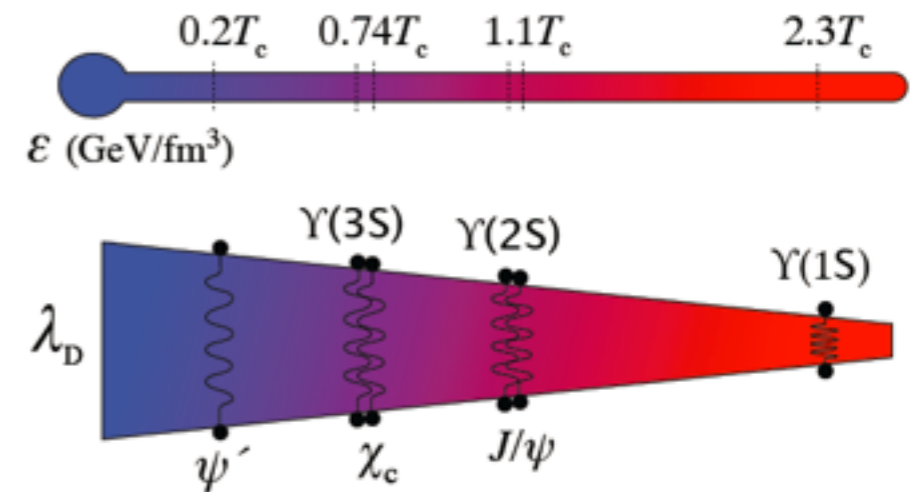
Why LHC and RHIC?

A comparison of as many heavy quarkonia systems as possible at multiple initial temperatures offers the best prospect for extracting the effects of color screening on quarkonia in the presence of the other competing effects.

By comparing quarkonia yields in p+p, p(d)+A and A+A collisions at RHIC and LHC energies we:

- Change the initial temperature by ~ 30%
- Change the underlying heavy quark production cross section
- Change details of the cold nuclear matter modification

J/ψ at RHIC and LHC (why are we not done yet?

Comparison of ALICE and PHENIX data shows that at the same energy density the R_{AA} is much smaller at RHIC.

- Consistent with predictions that coalescence of charm pairs will dominate at LHC energy
- Supported by v_2 of J/ψ at LHC
- Cool! But we do not get a direct comparison of screening effects at RHIC and LHC from the J/ψ
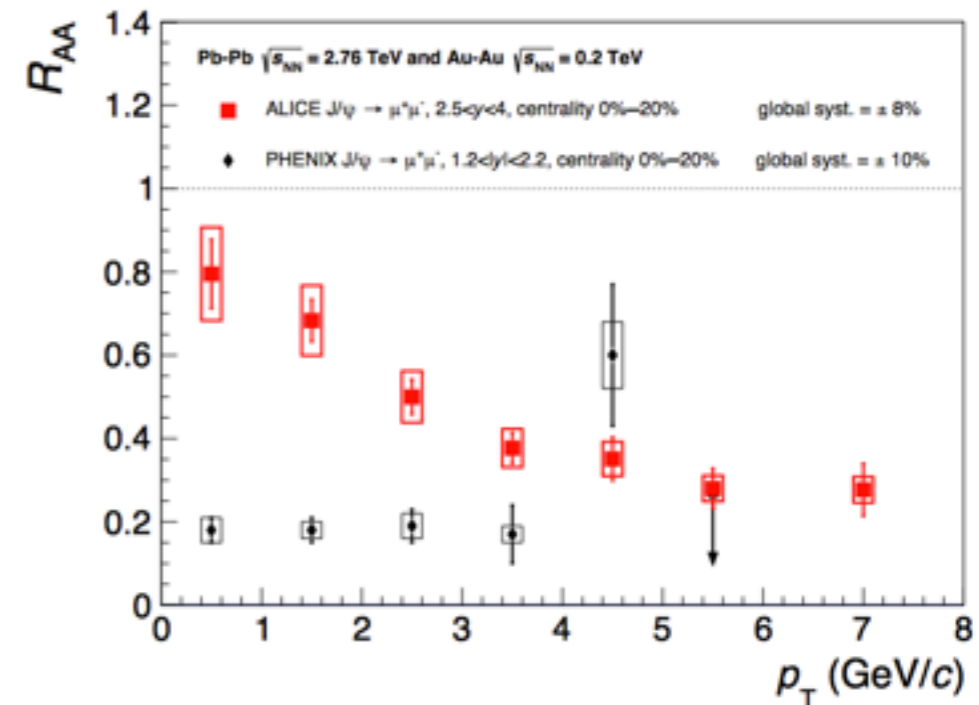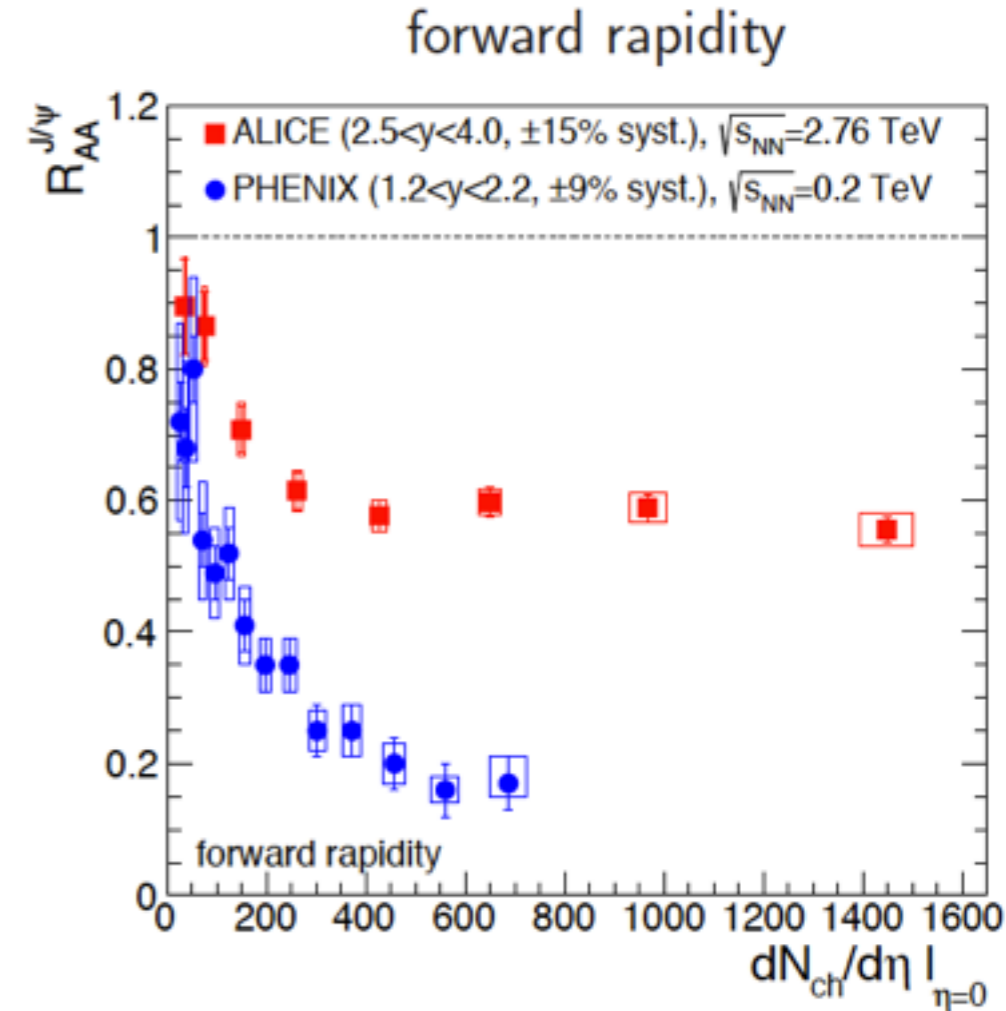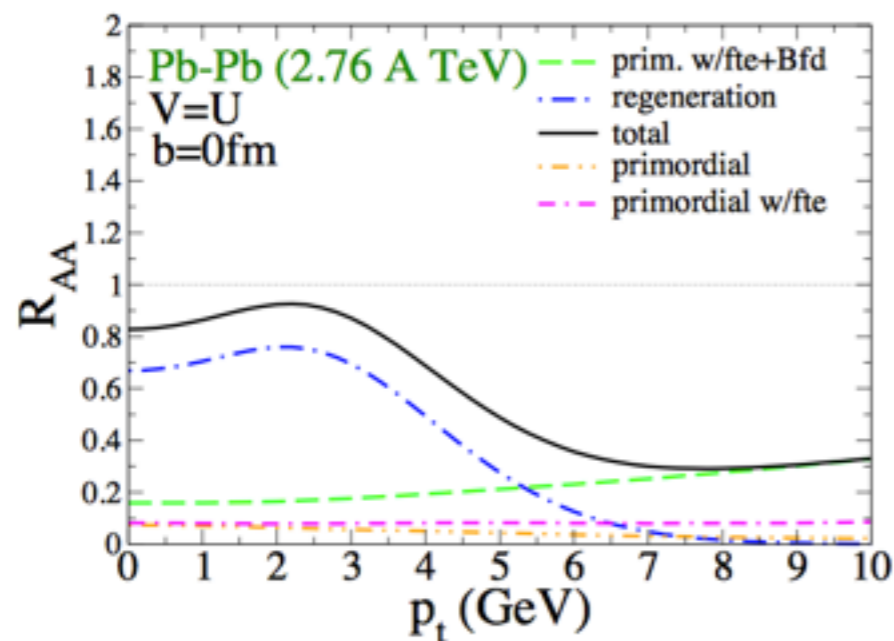
We want to compare color screening effects on states of different size vs initial temperature.

The Y(1S), Y(2S) and Y(3S):

- Span a broad range of sizes
- Are accessible in the same experiment via e^+e^- or $\mu^+\mu^-$
- Have similar nPDF's
- Will not have a large coalescence contribution at RHIC **or** LHC
  - Bottom pairs in central events at LHC similar to charm pairs at RHIC

By the end of Run 3 there will be **very** precise Upsilon data from the LHC

Tracking with sufficiently good momentum resolution in sPHENIX enables very precise Upsilon measurements at RHIC energies on a similar time scale.
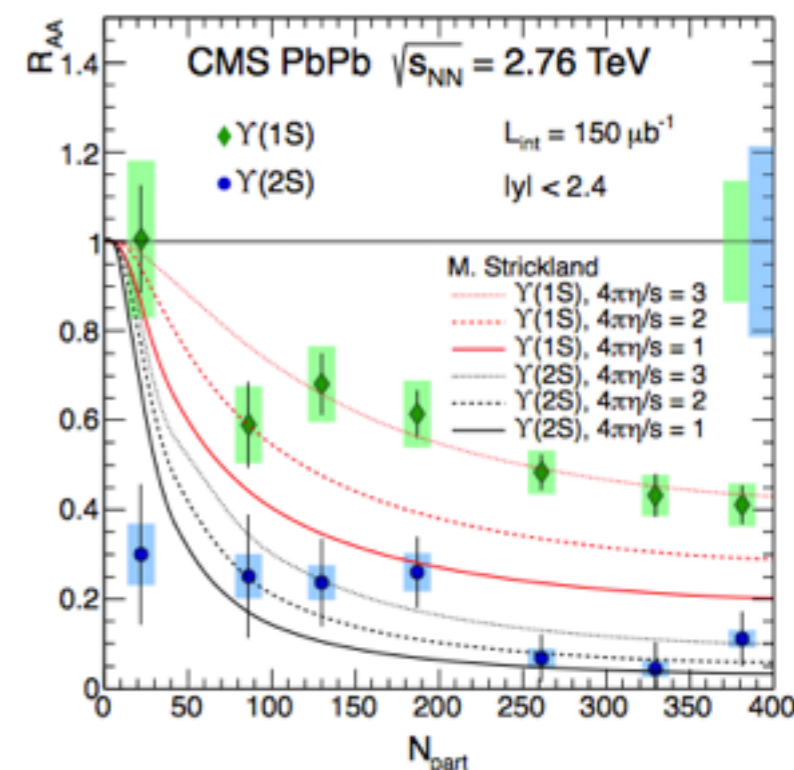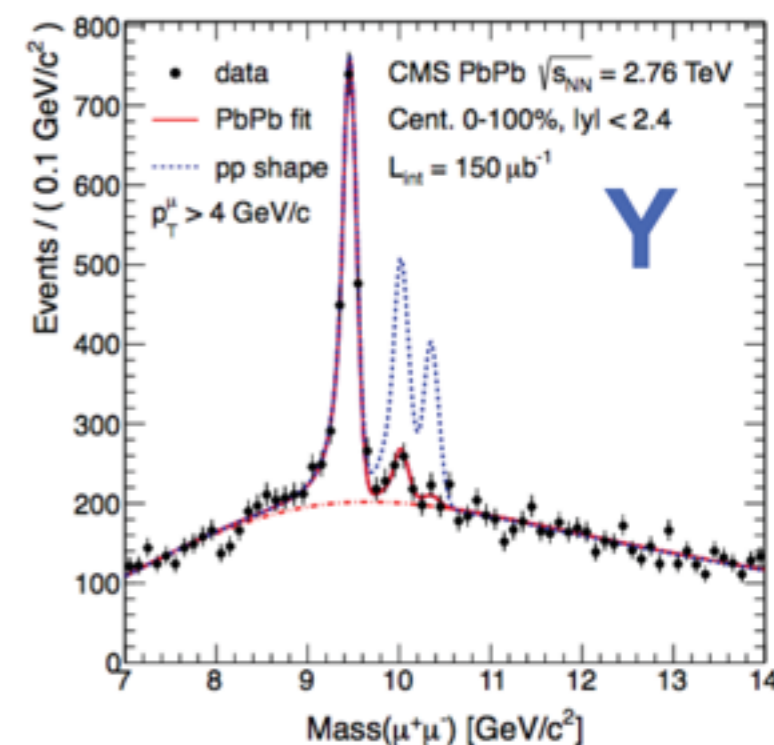
Upsilon measurements

We plan to measure Upsilons in sPHENIX using their dielectron decays. This requires that we have:

- Precise tracking to obtain mass resolution of 100 MeV or less
- Low mass tracking to limit electron radiative energy loss
- Electron ID (hadron rejection) using matching to the CEMC
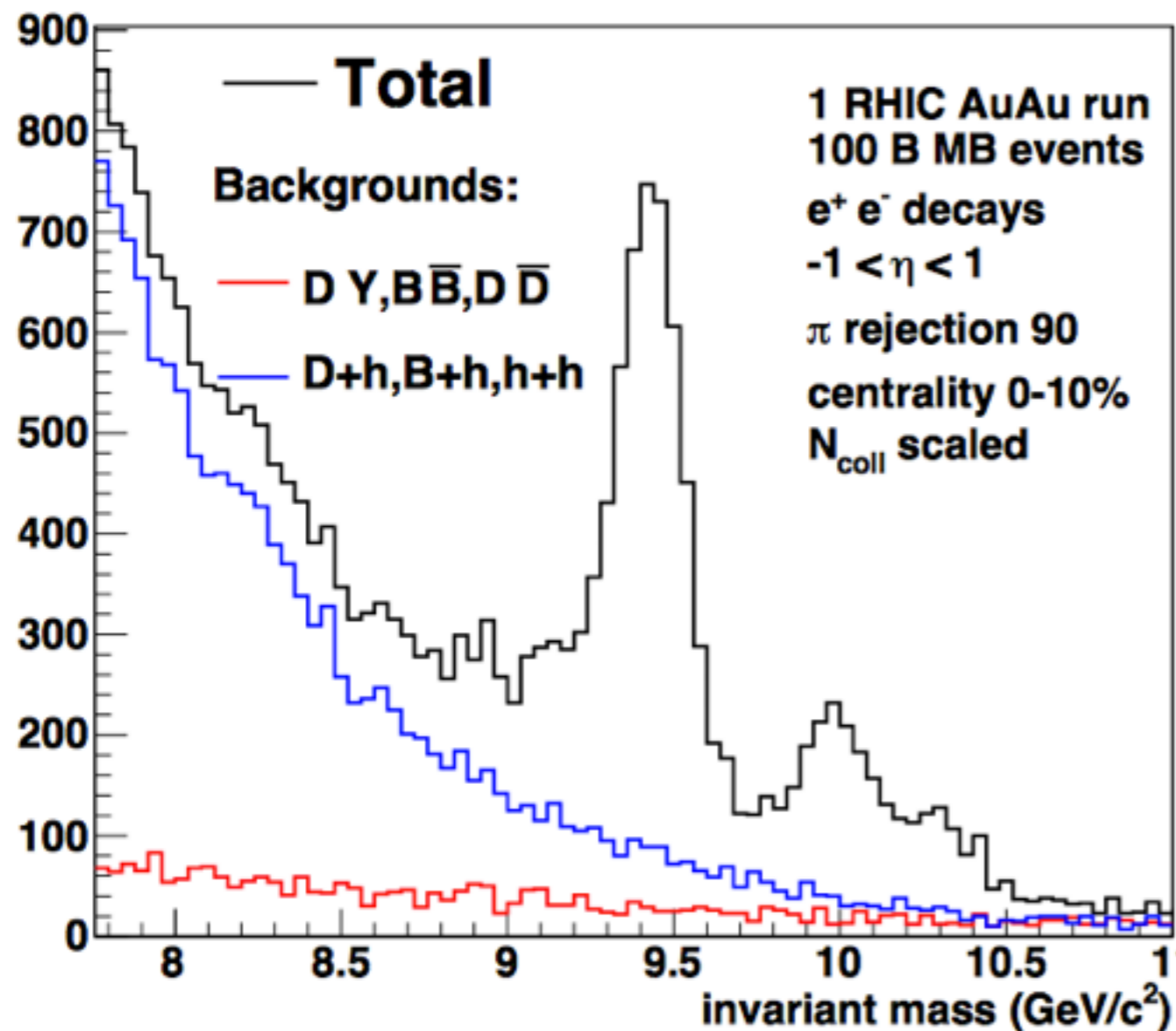- Very good tracking efficiency

These are the factors that drive the (still evolving) tracker design, and have heavily influenced the CEMC design.
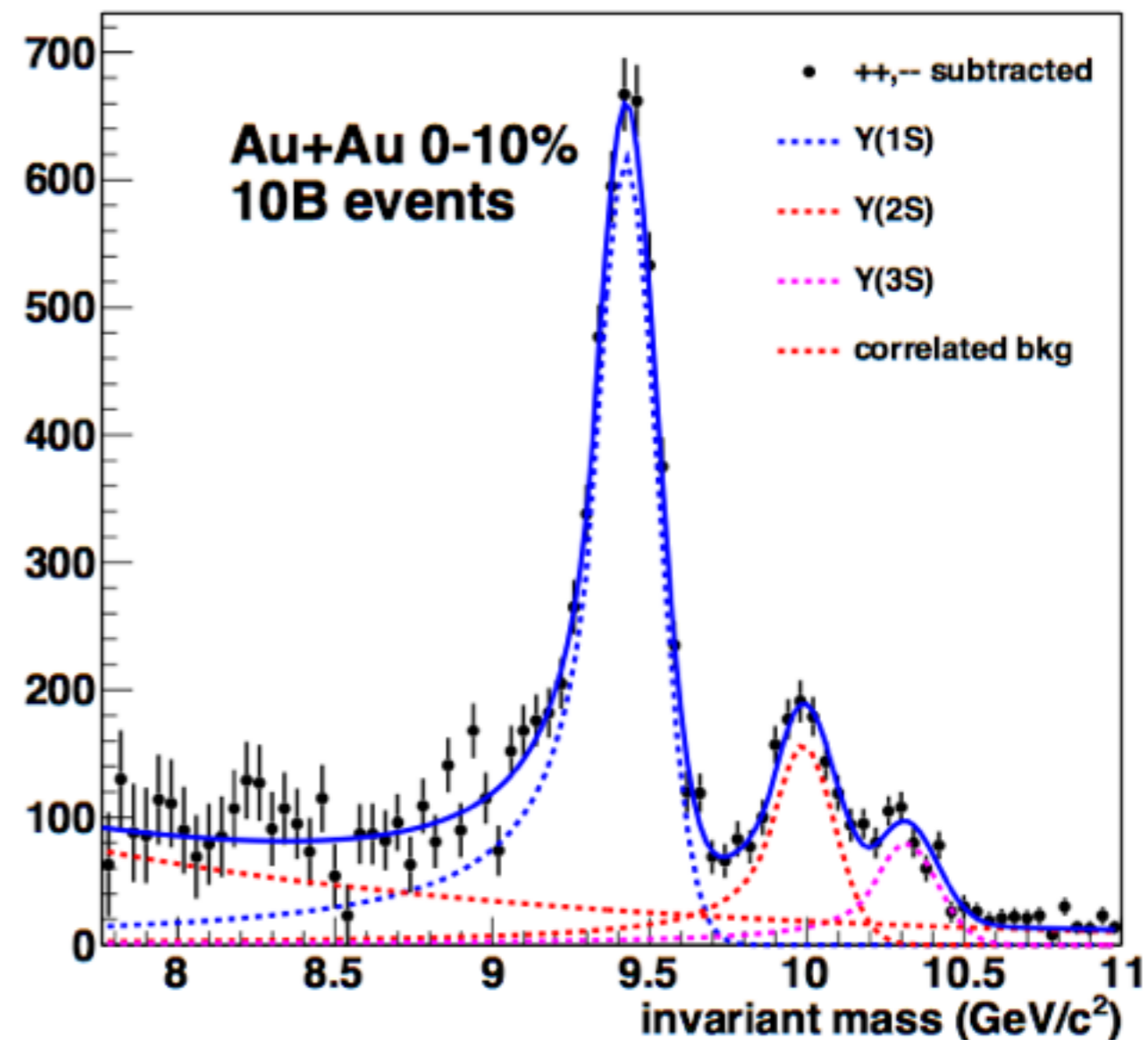
Geant 4 simulation of the mass distribution
Fast simulation of the background based on measured pion yields
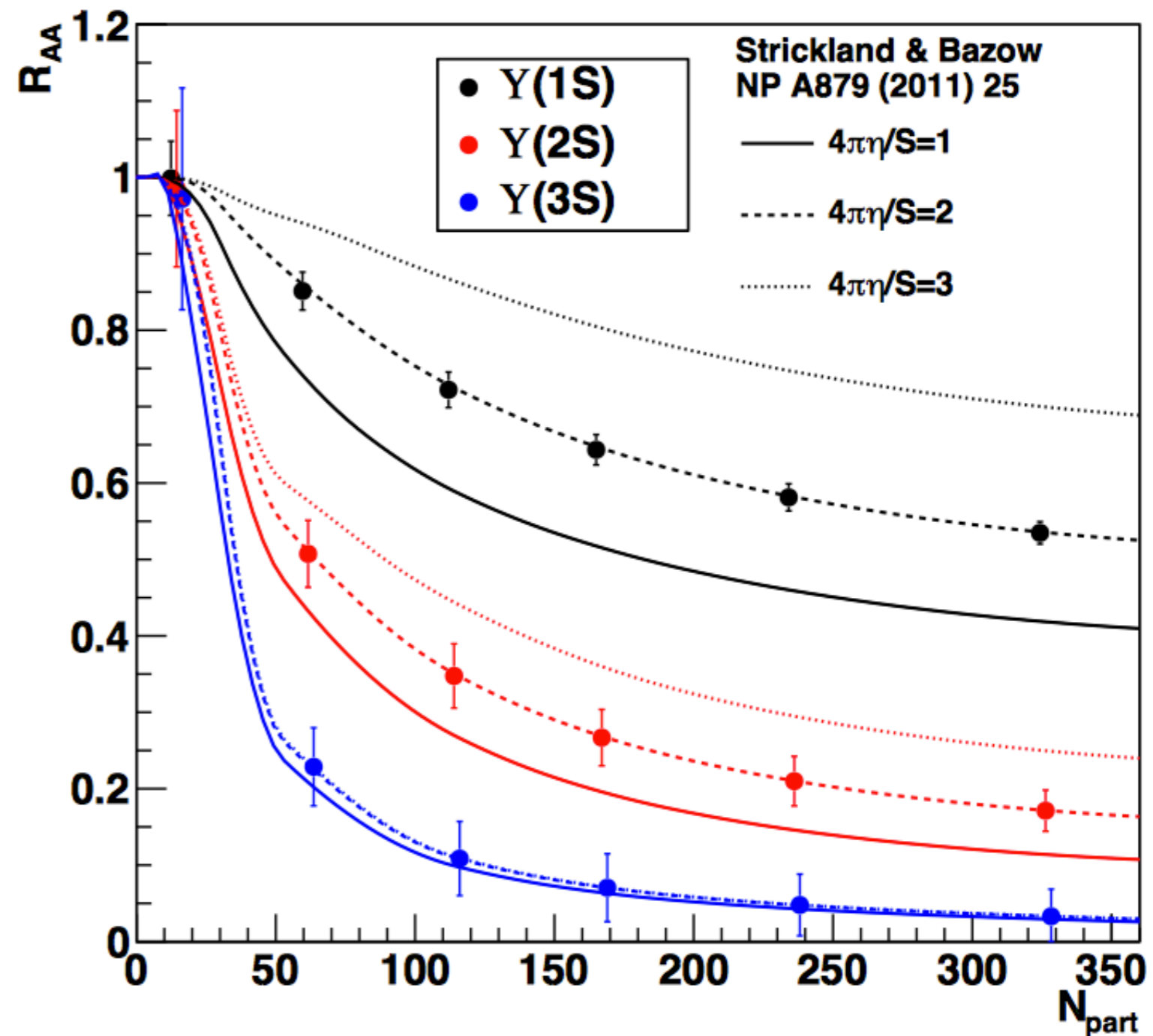
Projected R$_{AA}$ vs centrality

- 22 weeks of Au+Au
- 10 weeks of pp

Uncertainties on "data points" calculated using suppression from the model

Both yields and S/B scaled down to match model suppression

Centrality bins (%):
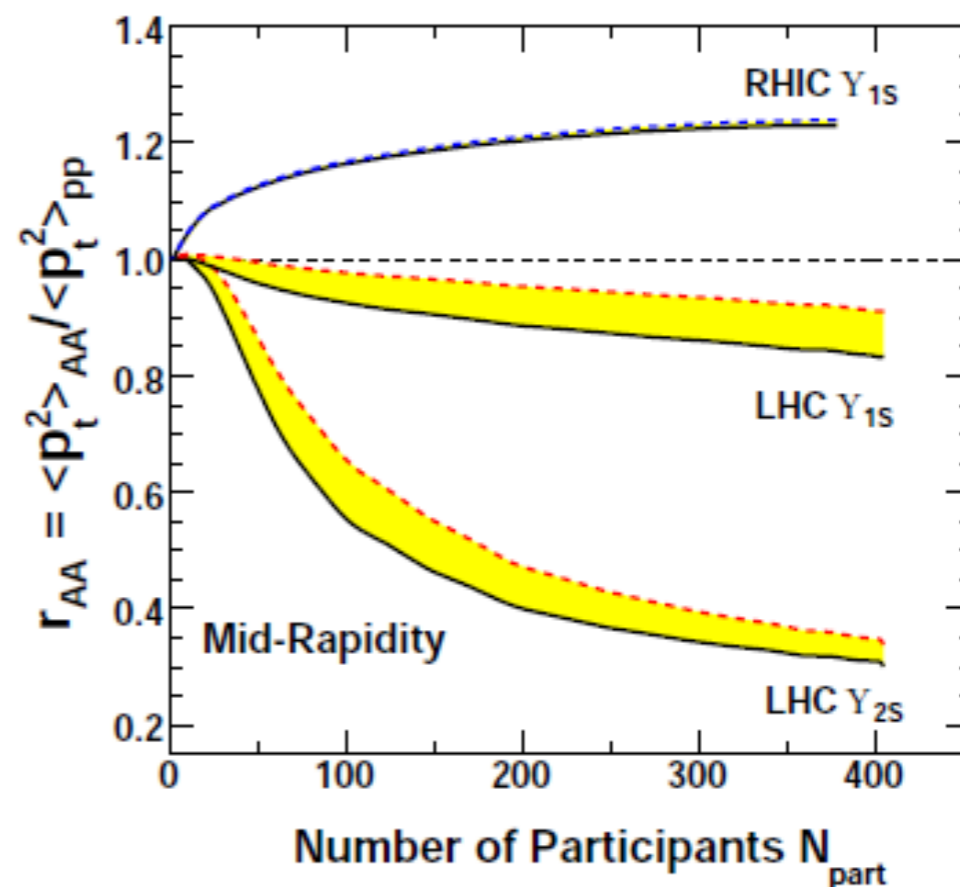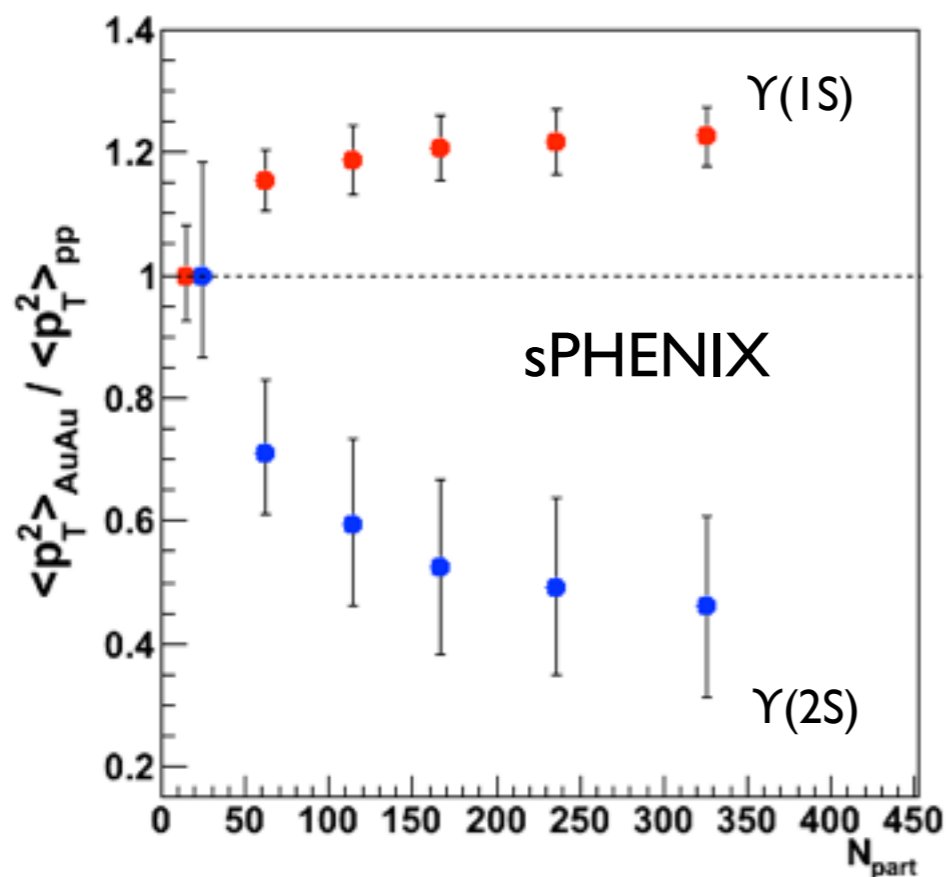0-10, 10-20, 20-30, 30-40, 40-60, 60-92

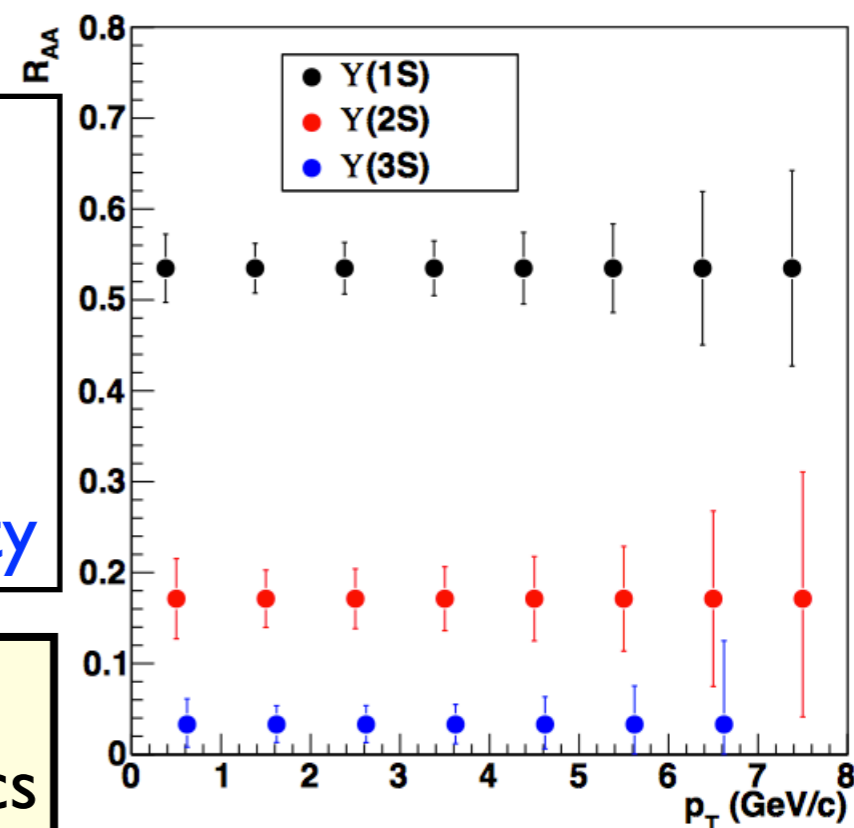# Upsilon R$_{AA}$ projections - AuAu p$_T$ dependence

Follows Strickland and Bazow calculated suppression

Reduce yield and S/B accordingly

Projected R$_{AA}$ vs p$_T$ for 22 weeks of Au +Au running, 0-10% centrality

Prediction of $\langle p_T^2 \rangle$ for Υ(1S) and Υ(2S) in Au+Au relative to p+p (Zhou et. al. arXiv1309.7520) and sPHENIX statistics

What about J/ψ measurements?

What J/ψ physics still needs to be done at RHIC energy for comparison with LHC data?
- Low p_T J/ψ R_{AA} have been done well in PHENIX (see slide 6)
- Higher p_T J/ψ R_{AA} is best done by STAR, but statistics are limiting.
  - ALICE has nice measurements (see slide 6)
- There is not yet a compelling J/ψ v_2 measurement at RHIC.
  - v_2 tests the size of the charm coalescence contribution.
  - ALICE will eventually have a precise measurement

Measuring inclusive or prompt J/ψ in sPHENIX will be a tough game.
- sPHENIX ~ 100:1 (CEMC matching)
- PHENIX ~ 1000:1 (RICH + EMCal matching)

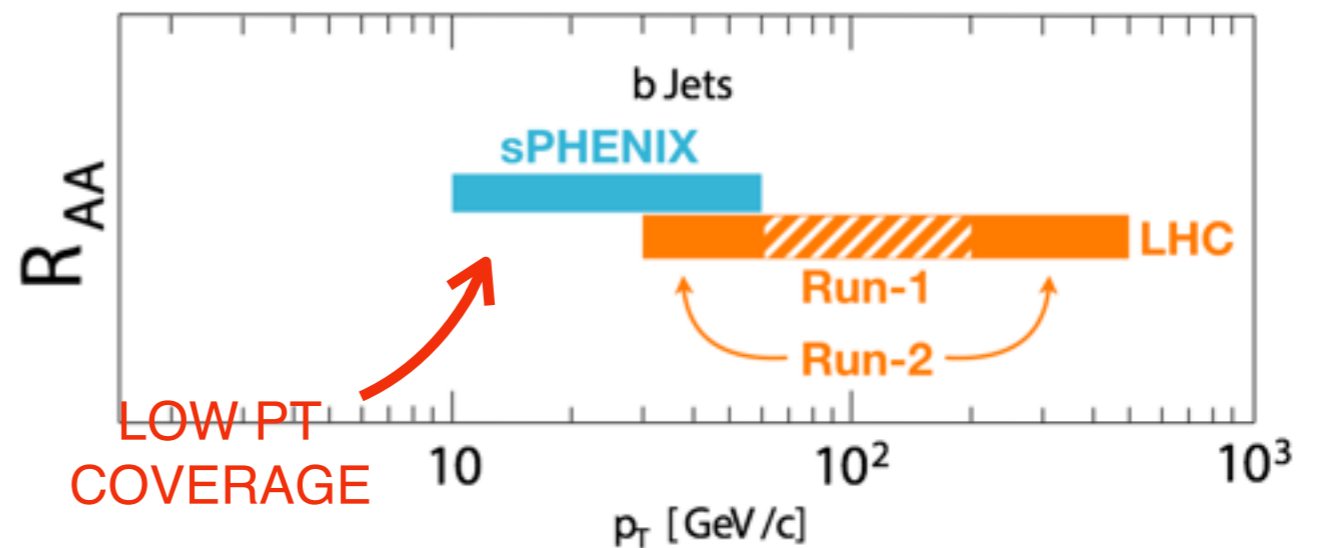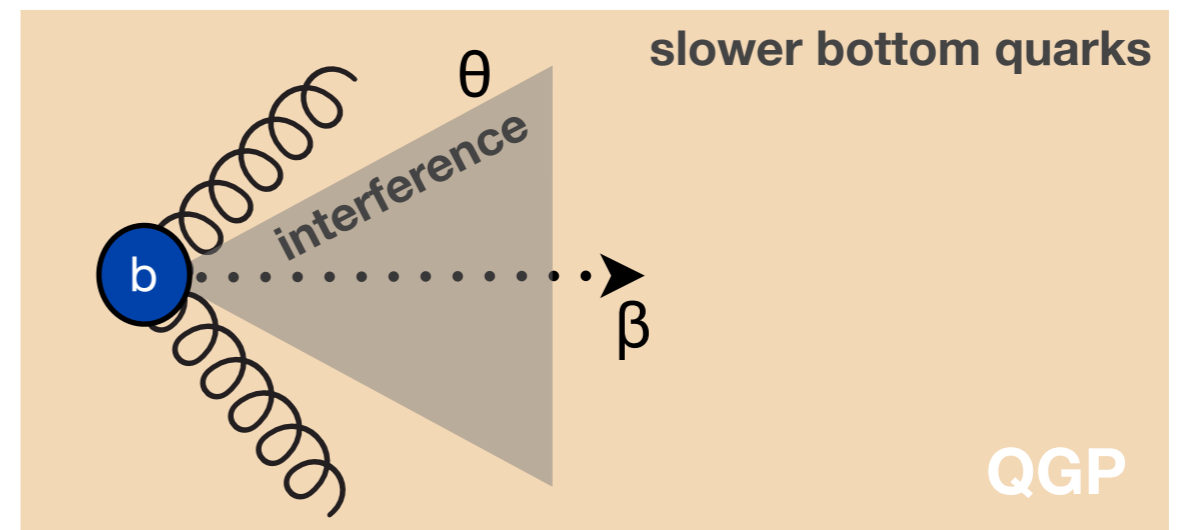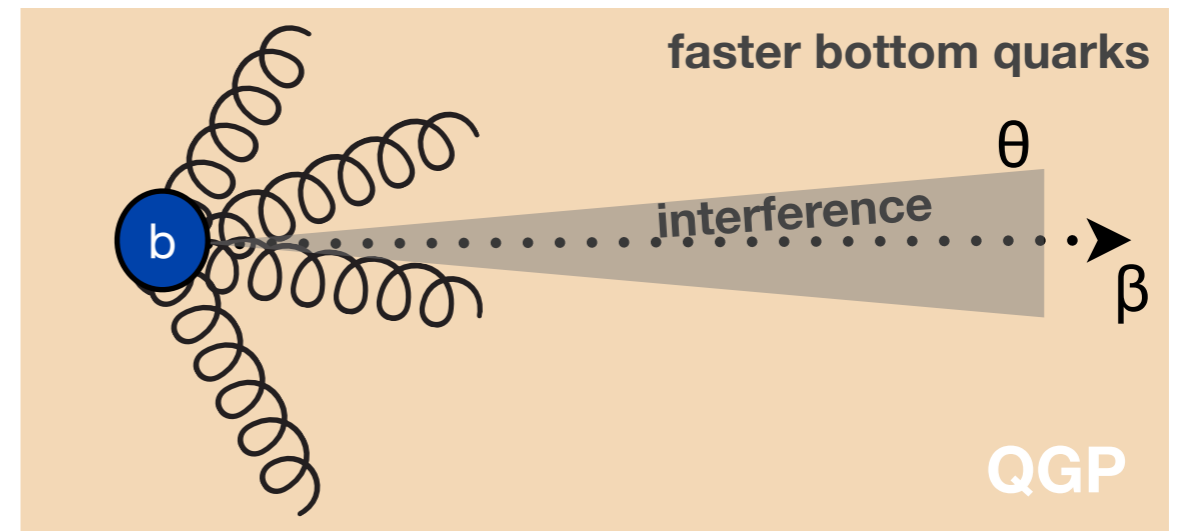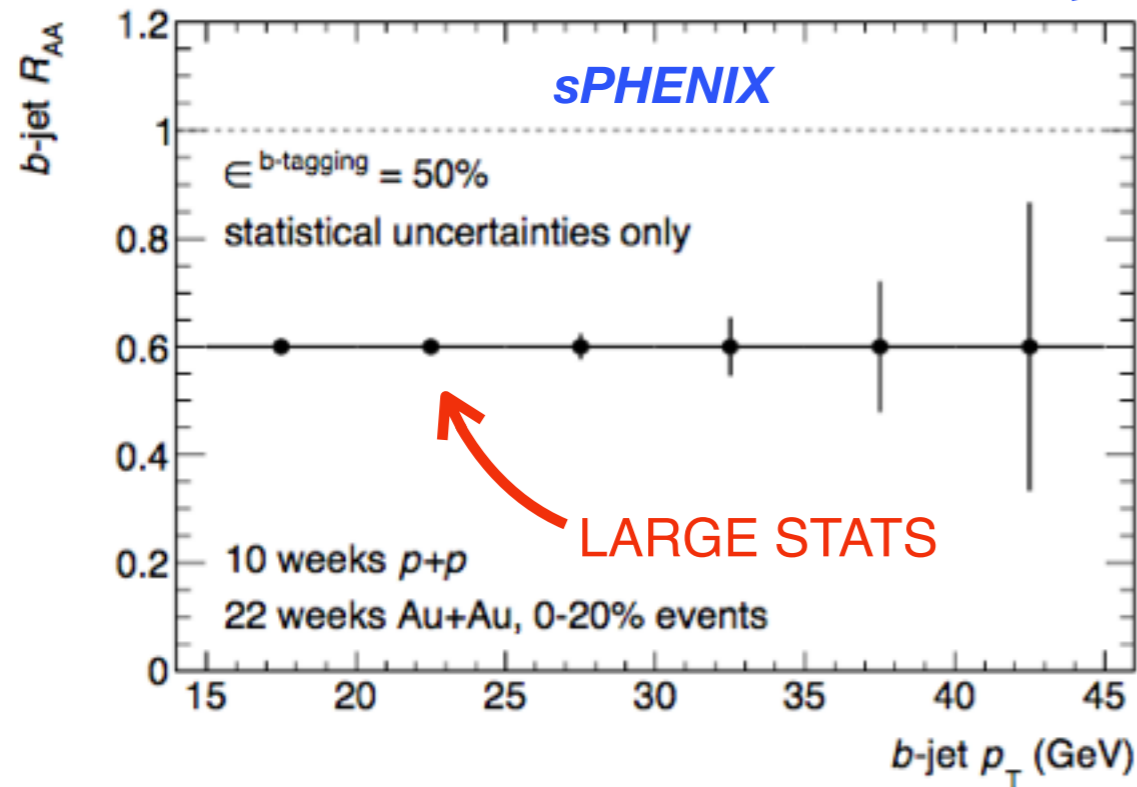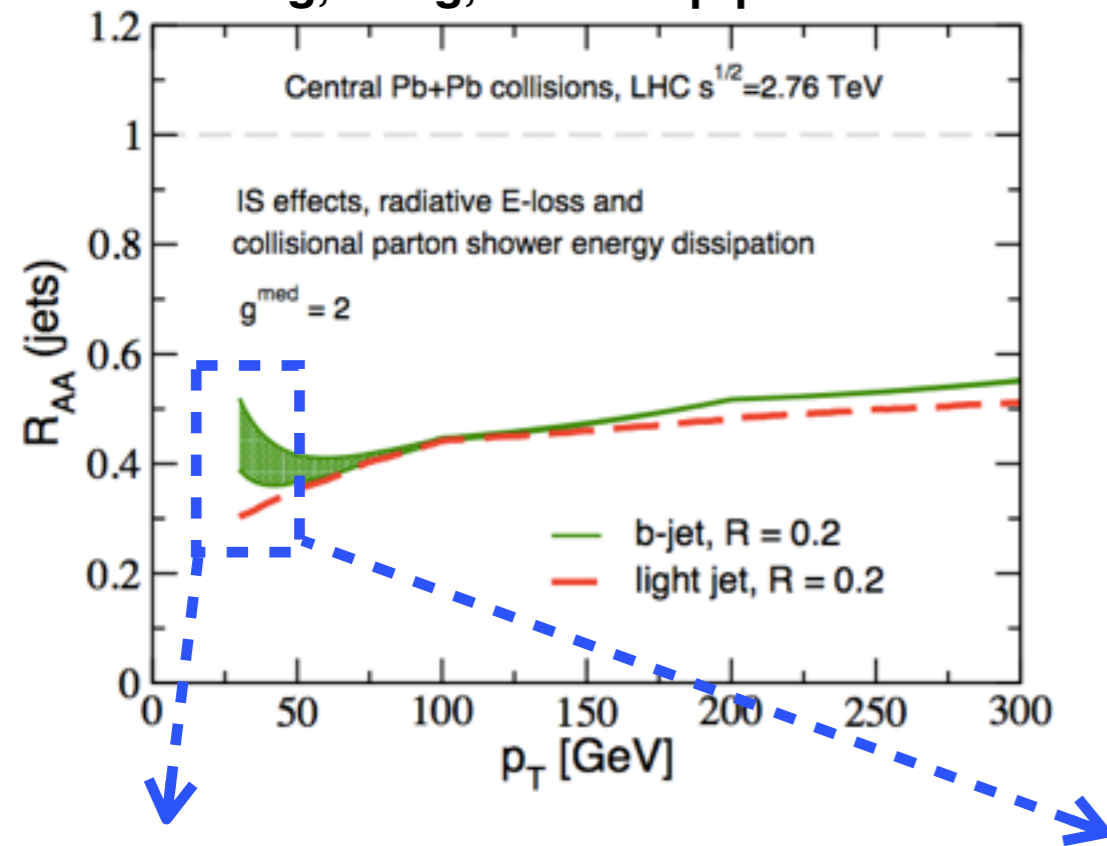If the TPC wins the tracking role, it will provide some additional eID from dE/dx. This is worth pursuing in simulations
- Could we get v_2?
- Could we get R_{AA} for higher p_T?

Open Heavy Flavor

Huang, Kang, Vitev: hep-ph/1306.0909

Central Pb+Pb collisions, LHC $s^{1/2}$=2.76 TeV

IS effects, radiative E-loss and collisional parton shower energy dissipation

$g^{med} = 2$

- b-jet, R = 0.2
- light jet, R = 0.2

sPHENIX

$\in^{b\text{-tagging}} = 50\%$

statistical uncertainties only

LARGE STATS

10 weeks $p+p$

22 weeks Au+Au, 0-20% events

faster bottom quarks

interference

θ

β

QGP

slower bottom quarks

θ

interference

β

QGP

b Jets

sPHENIX

LHC

Run-1

Run-2

LOW PT COVERAGE

14

B-jet Identification Methodology
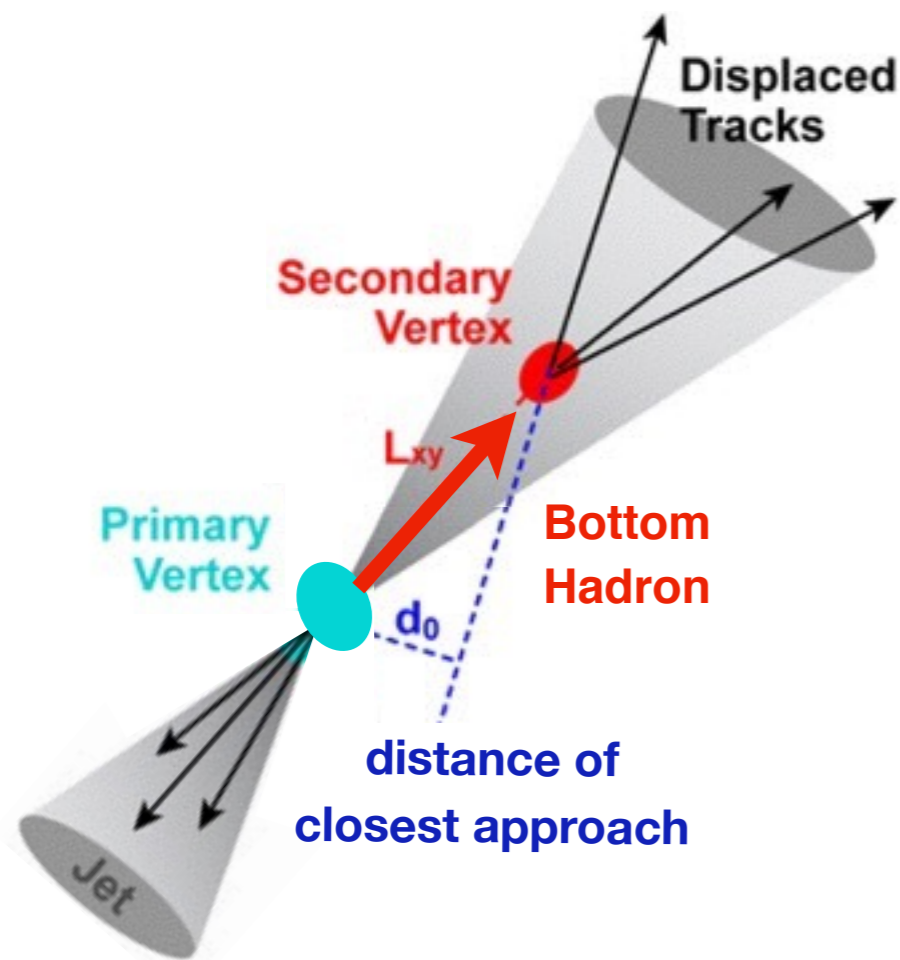
sPHENIX should have access to 3 different techniques for heavy-flavor identification:

(1) Semi-leptonic decay

(2) Multiple Large DCA tracks

(3) Secondary Vertex Mass

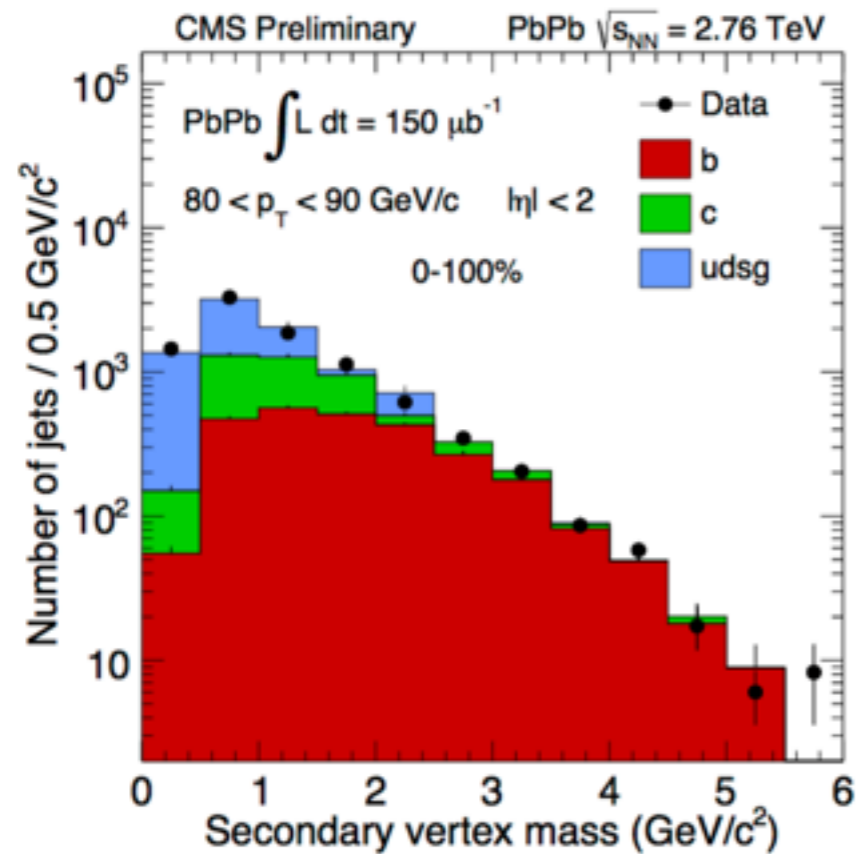**Big push from DVP for sPHENIX proposal**

Unexplored thus far!

All three methods require measurement of track DCA by the inner silicon.

(2) is relatively forgiving of DCA resolution, but sensitive to track efficiency
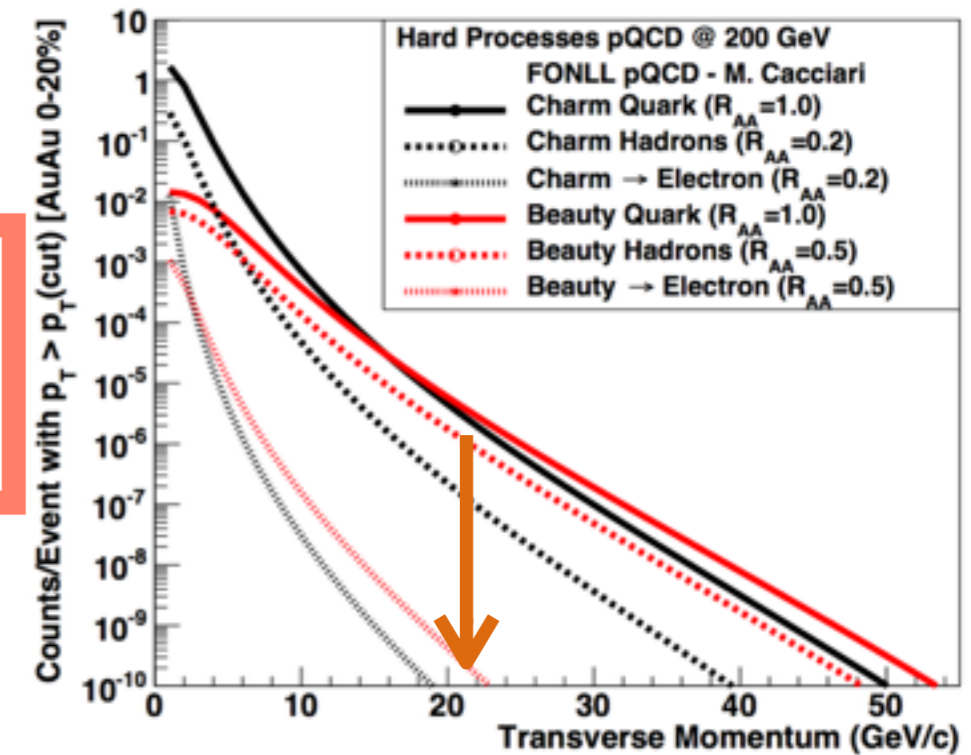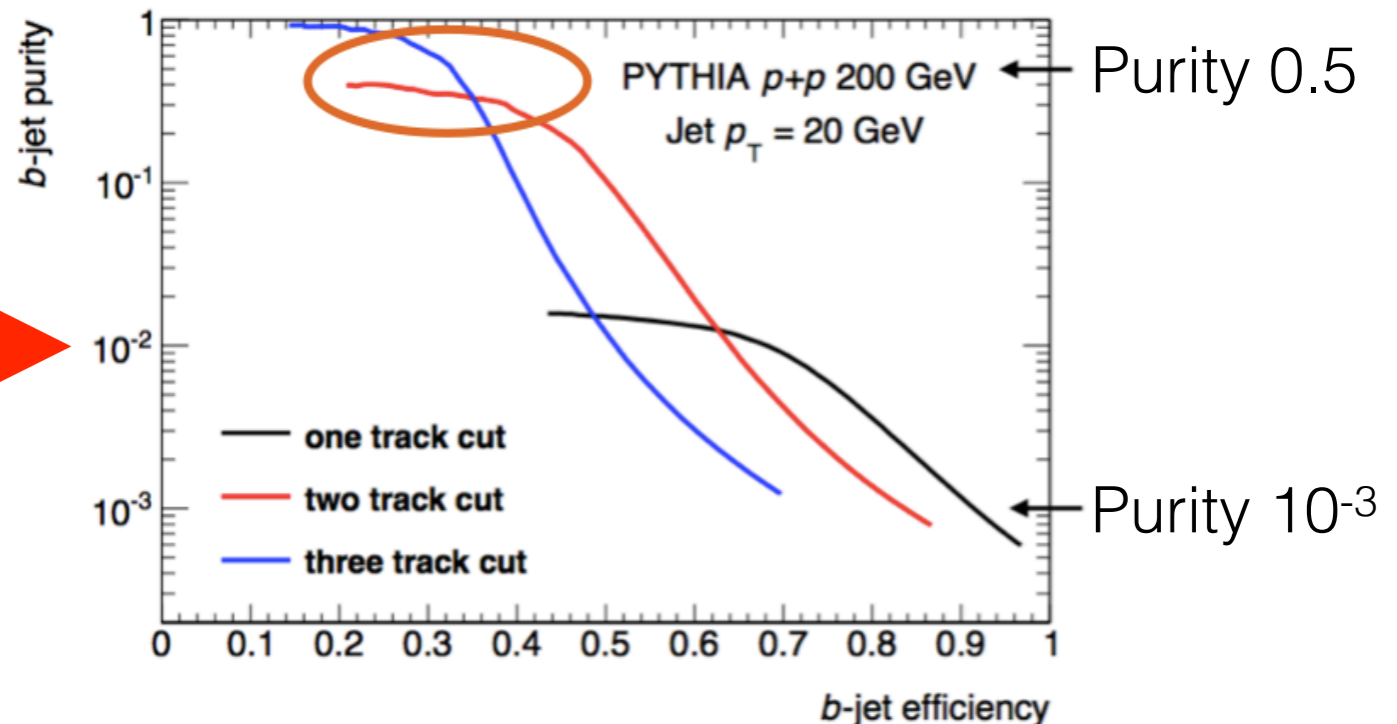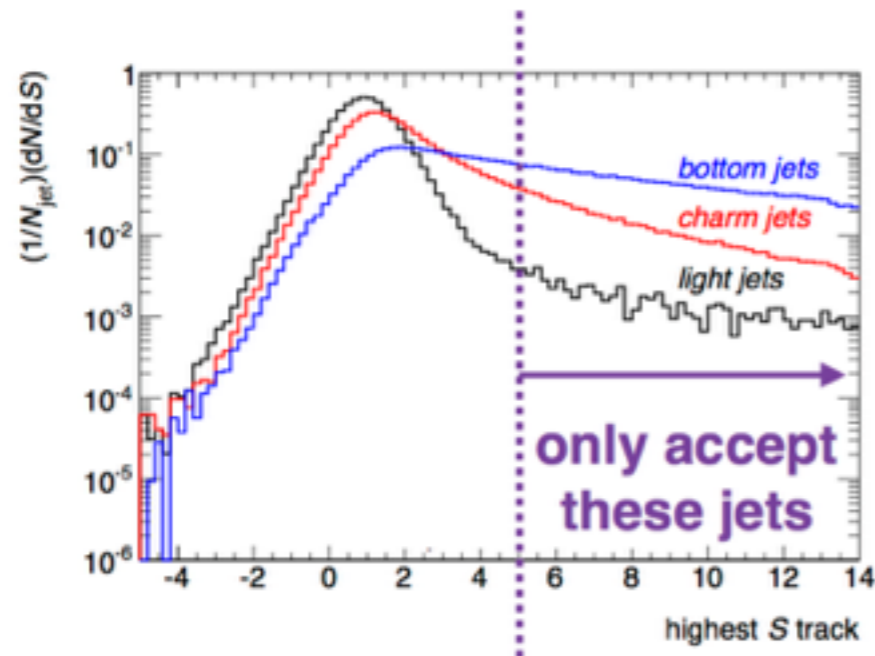(1) and (3) require excellent DCA resolution

(3) Secondary Vertex Mass

(1) Semi-leptonic decay

Large reduction in yield when using leptons

cut at some value S_{DCA}

(2) Multiple Large DCA tracks

Purity 0.5

Purity 10^{-3}
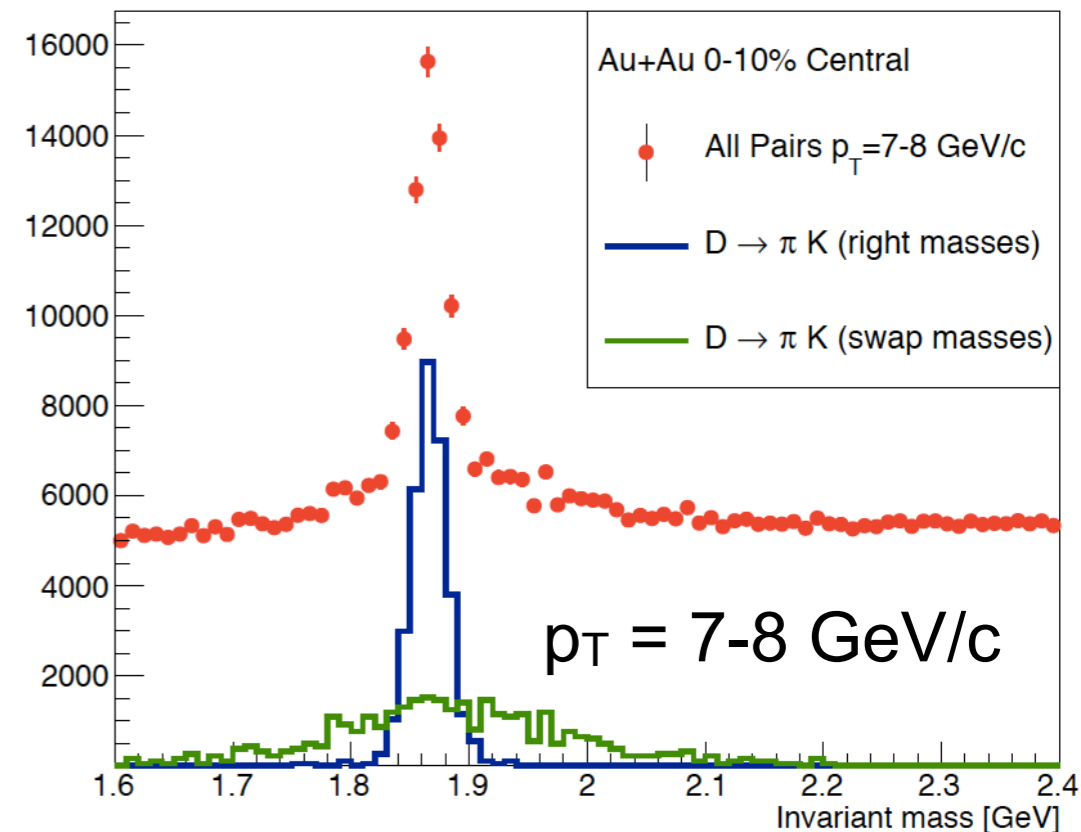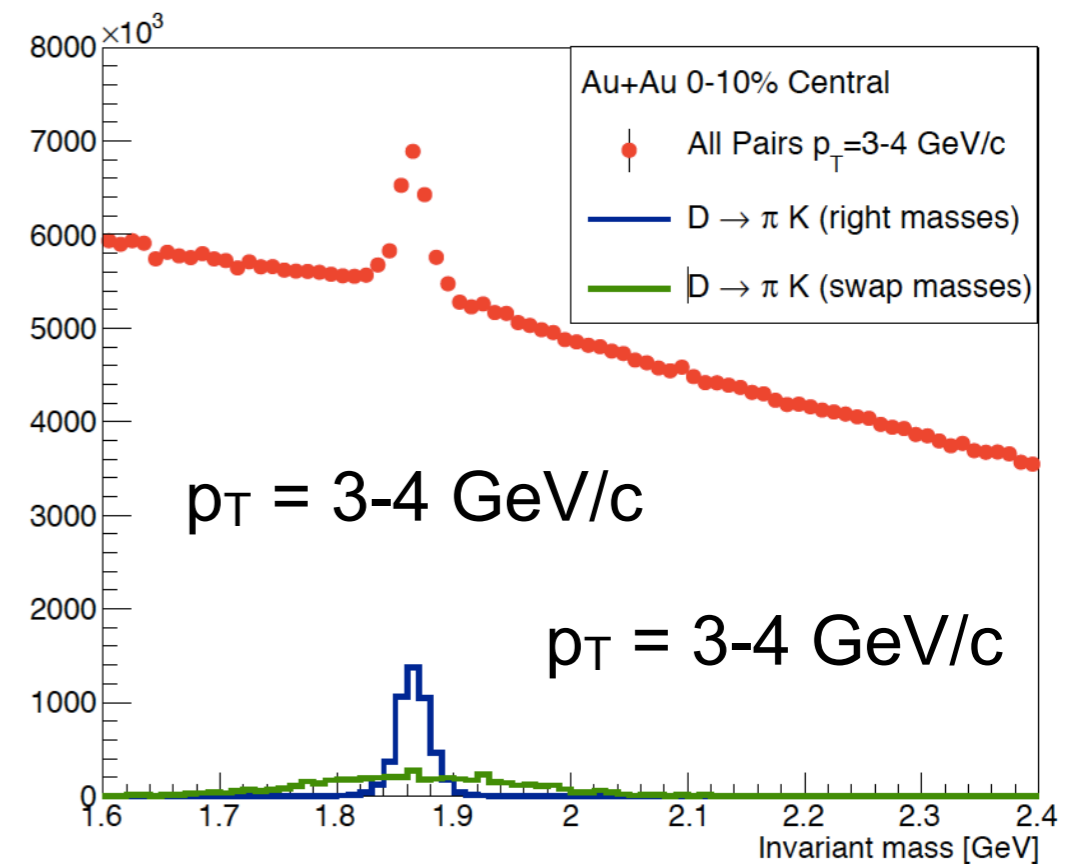
16

D meson reconstruction

The methods described earlier for b jet tagging are not very useful for tagging D jets. But it is possible in sPHENIX to reconstruct D mesons directly.

Red points show the mass spectrum of reconstructed D mesons in central Au+Au, using non-prompt unidentified charged tracks. Assumes each track is due to **both** a K and π.

- Blue points show true D peak when π and K are assigned the correct masses.
- Green points show true D peak when π and K are assigned the wrong masses.

The reconstructed D mesons can be associated with reconstructed jets in the calorimeters.

This measurement will require both excellent momentum resolution and excellent DCA resolution.

p_T = 3-4 GeV/c

p_T = 3-4 GeV/c

Au+Au 0-10% Central
- All Pairs p_T=3-4 GeV/c
- D → π K (right masses)
- D → π K (swap masses)

Invariant mass [GeV]

Au+Au 0-10% Central
- All Pairs p_T=7-8 GeV/c
- D → π K (right masses)
- D → π K (swap masses)

p_T = 7-8 GeV/c

Invariant mass [GeV]

B decays to J/ψ

J/ψ reconstructed from non-prompt dielectron pairs are a clean way to measure open bottom yields.

This has not been explored yet for sPHENIX, but we will want to do it.

What can you do?

If any of these measurements interest you, we could use lots of help! For example:

So far, the Upsilon simulations results that we have are persuasive but preliminary:
- We need studies of the signal to background for Upsilon measurements that are more realistic than our present fast simulations. It is critical to the physics that we have this right!
- Can we develop strategies to reduce radiative tails on Upsilon mass peaks?

We need performance studies for all three B jet tagging methods in sPHENIX. We will want to use at least two of them for analysis of the data.
- This is a major leg of the physics program, and we need to understand our capabilities in much better detail.
- Effect of DCA resolution, dead pixels, fake tracks.
- The B jet studies may be "make-or-break" for the reused pixels option.

We need D meson reconstruction performance studies to understand the effect of inner pixel + outer tracker performance on these measurements.
- They would obviously benefit from better DCA resolution, but what is good enough?
- What demands do these measurements place on fake track rates?